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(12) # EUROPEAN PATENT APPLICATION


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(54) **Method and apparatus for processing workpieces by ultrasonic energy.**


(57) An ultrasonic processing method and apparatus are disclosed wherein during the processing time interval the motional amplitude of the resonating horn and thereby the power to the workpiece is changed responsive to the production of a control signal. The control signal is process related and generated, in a typical example, when there is sharp rise in the power curve. In another example, the power is changed responsive to a changing dimension of the workpiece. In typical examples, the control signal reduces the motional amplitude for the remaining time interval.


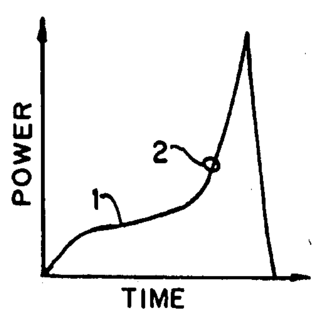


FIG.1.

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BRIEF SUMMARY OF THE INVENTION.

This invention concerns a method and apparatus for processing workpieces by ultrasonic energy and, more specifically, refers to a method and apparatus for processing thermoplastic workpieces using vibratory energy in the ultrasonic frequency range for bonding, sealing or welding thermoplastic film and fabric materials as well as substantially rigid workpieces. Quite specifically, this invention concerns a method and apparatus wherein the motional amplitude of the ultrasonically resonating horn in contact with the workpiece is varied during the processing time interval, thereby changing the power transmitted from the horn to the workpiece during such interval.

Welding thermoplastic workpieces and plunge sealing film and fabric materials by ultrasonic energy is well known. Generally, the workpiece is supported on an anvil. A horn, dimensioned to be resonant as a half wavelength resonator for high frequency vibrations of predetermined frequency traveling longitudinally therethrough, is brought into forced engagement with the workpiece for a time interval and, responsive to the horn being rendered resonant, ultrasonic energy is transmitted to the workpiece for causing a softening and flowing of thermoplastic material of the workpiece. Upon the cessation of the flow of ultrasonic energy, the softened and flowed material rigidifies, thereby establishing a bond or a weld.

In the past, it has been the common practice to retain the motional amplitude of the horn, i.e. the peak-to-peak mechanical excursion of the frontal horn surface in contact with the workpiece, constant during the entire time interval during which the horn is rendered resonant and transfers power to the workpiece. The present invention discloses an arrangement and method in which the motional amplitude of the horn, and thereby the ultrasonic power transmitted, is varied during the processing time interval in response to a control signal which may be responsive, for instance, to a change in power transmitted from the horn to the workpiece, a process related change of the workpiece dimension, a process related timing signal, or some other process related parameter.

The invention, which will be described in detail hereafter, has been made possible by the devlopment of an improved electronic power supply disclosed in U.S. Patent No. 4,973,876 issued to A.J. Roberts, dated November 27, 1990, entitled "Ultrasonic Power Supply", which patent is specifically incorporated herein for reference. This power supply includes control means for adjusting the motional amplitude of the horn independent of other parameters.

It has been discovered that a change of the motional amplitude of the horn effected during the time interval during which ultrasonic energy transfer to the workpiece occurs produces improved results when welding workpieces and diminishes tool wear, particularly in a condition in which the horn frontal surface strikes a metal anvil, as,for instance,in plunge sealing and cutting thermoplastic film and fabric materials.

One of the important objects of this invention is, therefore, the provision of an improved method for processing thermoplastic workpieces by the application of ultrasonic energy.

Another important object of this invention is the provision of an apparatus for varying during the processing time interval the motional amplitude of the ultrasonically vibrating horn in forced engagement with a workpiece.

A further important object of this invention is the provision of a method for processing workpieces by ultrasonic energy and varying the power transmitted to the workpiece in response to a process related control signal.

Still other and furthe! objects of this invention will become more clearly apparent from the following description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING.

FIGURE 1 is a graph depicting power vs. time in a typical ultrasonic cut and seal operation;

FIGURE 2 is a graph similar to FIG. 1, but reducing the motional amplitude of the horn when the power attains a predetermined level;

FIGURE 3 is a graph similar to FIG. 1 when producing a filter comprising two superposed non-woven materials;

FIGURE 4 is a graph of power vs. time when the power level is reduced during the time interval of producing a filter;

FIGURE 5 is a schematic illustration of a typical embodiment of an appartus for the invention;

FIGURE 6 is a schematic illustration showing an alternative embodiment of an apparatus for the invention;

FIGURE 7 is a schematic illustration of a further alternative embodiment of an apparatus for the invention;

FIGURE 8 is a schematic illustration of still another embodiment of an apparatus suitable for the invention, and

FIGURE 9 is a schematic electrical circuit diagram.

## DETAILED DESCRIPTION OF THE INVENTION.

Referring now to the figures and FIGURE 1 in particular, there is shown a graph of power applied from the horn to the workpiece in a typical plunge type ultrasonic seal and cut operation, wherein two thermoplastic film or fabric materials, superposed upon one another, are disposed on a metal anvil, and a horn is brought into forced contact with the exposed workpiece surface to simultaneously cut through the two layers, separating them from the surrounding stock material, and welding the two layers of material along the cut edge. A typical example is the manufacture of a circular filter pad. Upon the horn contacting the workpiece with a predetermined force, the horn is rendered resonant and ultrasonic energy is coupled to the workpiece, thus starting the time interval. As, after some passage of time, the horn cuts through the workpiece and the horn establishes contact with the metal anvil, the power flow, curve 1, rises rapidly as a result of the lower acoustic impedance of the anvil and the now reduced energy dissipation by the workpiece. The occurrence of such metal-to-metal contact is indicated by numeral 2. The power rises until the end of the time interval, generally a preset time interval.

The repetitive high frequency impact of the horn upon the anvil, occurring with a force of several thousand g, and the somewhat scrubbing motion of the horn causes a relatively rapid wear of the impacting anvil and horn surfaces, hence, necessitating early refinishing of the surfaces or replacement of the horn and anvil. In typical instances, the front surface of the horn becomes grooved and the knife shaped cutting surface of the anvil becomes dull.

FIGURE 2 shows the improved arrangement. In response to the rise of the power transfer, curve 3, corresponding to the metal-to-metal contact, point 4, a control signal is produced which, in turn, causes a reduction of the power transferred by reducing the motional amplitude of the horn. Thus, the power provided for the remainder of the cut and seal cycle is limited. The reduction of power has effected a dramatic reduction of the mechanical wear apparent at the frontal surface of the horn and at the raised anvil cutting surface.

FIGURE 3 depicts a graph of power vs. time when welding two superposed layers of non-woven thermoplastic material for producing a filter. The curve 5 is similar to that shown in FIGURE 1. As the filter material melts, there is evident a sharp transition between a good bond condition 6A and an overwelded condition designated by 6B. The power curve 5 provides a very narrow time window for achieving a good product.

FIGURE 4 shows the condition wherein by reducing the motional amplitude of the horn, numeral 7A, at the time the power increases sharply, indicating that the material has reached a melted condition, the window, distance 7A to 7B, for producing a good product is widened. It will be apparent that once the material has reached its melted state there is no need for increasing power. A relatively low power level will suffice to complete the processing cycle.

The novel arrangement disclosed heretofore is applicable also to the process of welding substantially rigid thermoplastic workpieces, for instance, when joining two parts, one being provided with a recess and the other part having a projection, also known as energy director, which responsive to the dissipation of ultrasonic energy melts and collapses, the molten material filling the recess, see, for instance, U.S. Patent No. 4,618,516 dated November 21, 1986, issued to T.B. Sager, entitled "Ultrasonic Welding of Thermoplastic Workpieces". After initial softening and flowing of thermoplastic material has occurred, the power necessary to complete the weld cycle is decreased and, hence, the motional amplitude of the horn reduced for the remainder of the weld cycle. The reduction in power has been observed to reduce the visible flash and the presence of voids in the weld. The voids result from cavitation and weaken the weld.

The control signal for effecting the reduction of the motional amplitude can be responsive to the value of the power provided to the workpiece as illustrated heretofore, or can be responsive to other parameters of the process. For example, the control signal can be produced in response to a predetermined amount of time elapsed in the weld cycle, or be responsive to a changing mechanical dimension of the workpiece assembly as sensed, for instance, by mechanical sensing means, optical sensing means, or an eddy current sensing device, see U.S. Patent No. 4,631,685 dated December 23, 1986 issued to D.A. Peter, entitled "Method and Apparatus for Ultrasonic Plastic Forming and Joining". Therefore, in a typical application, the reduction of power transmitted may be effected when fifty per cent of the collapse of the energy director is sensed or has been established experimentally. In the latter case, the control signal can be responsive to time elapsed in the weld cycle.

As will be apparent to those skilled in the art, the reduction of motional amplitude of the horn does not need to occur abruptly or as a single step. A varying or dynamic control signal may be provided, produced for instance by a function generator which is triggered upon the start of the weld cycle. In this manner, a continuously varying power output can be achieved. The latter arrangement is particularly useful when welding complex workpieces or when encountering difficult to weld plastic workpieces as caused by the composition of the thermoplastic material.

Figures 5 to 8 show schematically an apparatus for the present invention. As stated hereinabove, the power supply shown in U.S. Patent No. 4,973,876 which includes a voltage control circuit, see FIGS. 1 and 8 of the patent, is well suited for varying the power applied to the workpiece. With reference to FIGURE 5, the conductor 16 from the power supply 8 leads to a power meter 20 for sensing the electrical power supplied via conductor 17 to the elctroacoustic transducer 18, which is fitted with a horn 19. A comparator and latch circuit 21 receives a signal commensurate with the power to the transducer 18. An adjustment control 22 provides a variable reference signal adjustment to the comparator and when the power commensurate signal exceeds the reference signal, the comparator provides an output signal which is locked on by the latch circuit and fed as a control signal via conductor 21A to the voltage control circuit 500 forming a part of the power supply. The voltage control circuit, in turn, causes a change in the motional ammplitude of the horn as described in the patent supra.

FIGURE 6 shows schematically the use of a time responsive signal. Conductor 23 causes a set/reset signal to be applied to the clock and signal generator 24 actuated by a set signal responsive to the start of power flow to the transducer 18. When the clock circuit receives the signal via conductor 23 and the clock reaches a preset point in time, settable by adjustment 25, the signal generator via conductor 26 provides a control signal to the voltage control circuit 500 for changing the power level to the transducer. When the power transfer stops at the end of the time interval during which power flows, the circuit 24 is reset.

FIGURE 7 is a similar arrangement as shown in the preceding figures, except a function generator 28, started upon the receipt of a signal via conductor 27, sends a varying control signal via conductor 29 to the voltage control circuit 500.

FIGURE 8 depicts the horn 19 in forced contact with a worpiece W to be welded and supported on an anvil 30. A suitable sensing means 31, senses the change of dimension of the workpiece during welding together the two workpiece halves. As stated above, suitable sensing means comprise optical, electrical, acoustic or mechanical sensing means well known in the art. When the workpiece dimension changes to a predetermined value as noted by the control circuit 33 receiving a dimension responsive signal via conductor 32, a control signal is provided via conductor 34 to the voltage control circuit 500 of the power supply 8. Again, the control signal serves to cause a change in the motional amplitude of the horn and thereby a change in the power transmitted from the power.supply to the electro-acoustic transducer, horn and workpiece.

FIGURE 9 shows the voltage control circuit shown in the patent to Roberts supra. The amplitude control adjustment via variable resistor 518 shown in the patent has been eliminated and replaced by the control signal carrying conductor 21A, 26, 29 or 34. All other circuit features are as described in the patent.

Another application in which a function generator, FIG. 7, will be useful is the rotary drum sealing arrangement, see for example U.S. Patent No. 3,733,238 issued to D.D. Long et al, dated May 15, 1973 entitled "Apparatus for Vibration Welding of Sheet Material", or U.S. Patent No. 4,690,722 issued to G.N. Flood, dated September 1, 1987 entitled "Ultrasonic Apparatus for Joining and Severing Sheet Material". In such an application the function generator preferably provides a changing signal to cause a modulated power output. This can be achieved by a triangular, trapezoidal or sinusoidal control signal, or some other periodically changing signal.

While there have been described and illustrated certain preferred embodiments of the invention, it will be apparent to those skilled in the art that various further changes and modifications may be made without departing from the principle and spirit of this invention, which shall be limited only by the scope of the appended claims.

## Claims

1. An ultrasonic energy processing method in which a horn adapted to be mechanically resonant as a half wavelength resonator is brought into forced contact with a workpiece for transmitting ultrasonic energy thereto during a time interval, the improvement comprising: varying responsive to a control signal produced during said time interval the power transmitted by said horn to the workpiece.

2. An ultrasonic energy processing method as set forth in claim 1, said power being varied by varying the motional amplitude of said resonating horn.

3. An ultrasonic energy processing method in which a horn adapted to be mechanically resonant as a half wavelength resonator is brought into forced contact with a workpiece for transmitting ultrasonic energy thereto during a time interval, the improvement comprising: causing said horn to be resonant at a first motional amplitude at the start of the time interval and responsive to a control signal produced during the interval causing said horn to be resonant at a second motional amplitude.

4. An ultrasonic energy processing method as set forth in claim 3, said control signal being responsive to the ultrasonic power transmitted from said horn to the workpiece.

5. An ultrasonic energy processing method as set forth in claim 3, said control signal being responsive to a changing mechanical dimension of the workpiece.

6. An ultrasonic energy processing method as set forth in claim 3, said control signal being responsive to a time responsive signal produced during said time interval.

7. An ultrasonic energy processing method as set forth in claim 3, said second motional amplitude being lower than said first motional amplitude.

8. An ultrasonic energy processing method as set forth in claim 3, said control signal being responsive to a parameter of the process.

9. An ultrasonic energy processing method in which a a horn adapted to be mechanically resonant as a half wavelength resonator is brought into forced contact with a workpiece for transmitting when the horn is rendered resonant ultrasonic energy to the workpiece during a time interval, the improvement comprising: measuring the power transmitted from said horn to the workpiece and when the power attains a predetermined level producing a control signal, said signal causing the horn to be resonant at a lower motional amplitude than the amplitude at which the horn was resonant prior to the production of said control signal, and continuing the operation of said resonant horn at said lower motional amplitude during the remainder of the time interval.

10. An ultrasonic energy processing method as set forth in claim 9, the workpiece being thermoplastic material and the ultrasonic power transmitted causing a softening and flowing of thermoplastic material.

11. An ultrasonic apparatus including a power supply for providing electrical energy in the ultrasonic frequency range to an electroacoustic transducer provided with a horn whose frontal surface is adapted to be coupled to a workpiece for transmitting, when in forced contact with the workpiece and rendered resonant, power in the form of mechanical vibrations in the ultrasonic frequency range to the workpiece, the improvement comprising: means coupled for sensing the power transmitted to the workpiece and providing to the power supply a control signal responsive to the power transmitted for changing the power transmitted to the workpiece.

12. An ultrasonic apparatus as set forth in claim 11, said control signal causing a change of the motional amplitude manifest at the frontal surface of the horn.

13. An ultrasonic apparatus as set forth in claim 12, said control signal being responsive to the power transmitted to the workpiece attaining a predetermined value and causing the motional amplitude to be changed to a lower value.

14. An ultrasonic apparatus including a power supply for providing electrical energy in the ultrasonic frequency range to an electroacoustic transducer provided with a horn whose frontal surface is adapted to be coupled to a workpiece for transmitting, when in forced contact with the workpiece and rendered resonant, power in the form of mechanical vibrations in the ultrasonic frequency range to the workpiece, the improvement comprising: means disposed for sensing a changing dimension of the workpiece and providing in response thereto a control signal to the power supply for changing the power transmitted to the workpiece.

15. An ultrasonic apparatus as set forth in claim 14, said control signal causing a change of the motional amplitude manifest at the frontal surface of the horn.

16. An ultrasonic apparatus as set forth in claim 14, said control signal being responsive to a predetermined dimensional change and causing the motional amplitude to be changed to a lower value.

17. An ultrasonic apparatus including a power supply for providing electrical energy in the ultrasonic frequency range to an electroacoustic transducer provided with a horn whose frontal surface is adapted to be coupled to a workpiece for transmitting, when in forced contact with the workpiece and rendered resonant for a certain time interval, power in the form of mechanical vibrations in the ultrasonic frequency range to the workpiece, the improvement comprising: time responsive means coupled for providing during the time in-

terval a control signal to the power supply for changing the power heretofore transmitted to the workpiece during said interval.

**18.** An ultrasonic apparatus as set forth in claim 17, said control signal causing a change of the motional amplitude manifest at the frontal surface of said horn.

**19.** An ultrasonic apparatus as set forth in claim 17, said control signal causing the motional amplitude to be changed to a lower value.

**20.** An ultrasonic apparatus including a power supply for providing electrical energy in the ultrasonic frequency range to an electroacoustic transducer provided with a horn whose frontal surface is adapted to be coupled to a workpiece for transmitting, when in forced contact with the workpiece and rendered resonant, power in the form of mechanical vibrations in the ultrasonic frequency range to the workpiece for a time interval, the improvement comprising: means coupled for producing, responsive to a changing parameter resulting from the transmitting of power to the workpiece, a control signal during the duration of the time interval, said control signal causing a change of the motional amplitude of the horn and thereby changing the power transmitted to the workpiece during the remaining part of the time interval.

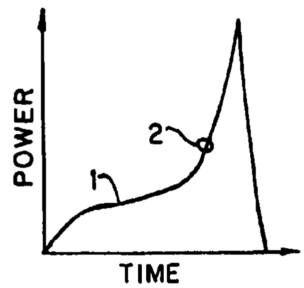


FIG.1.

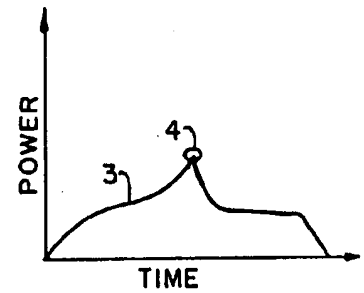


FIG.2.

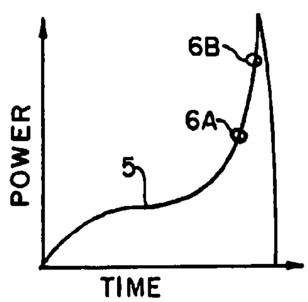


FIG.3.

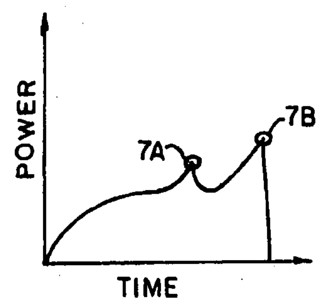


FIG.4.

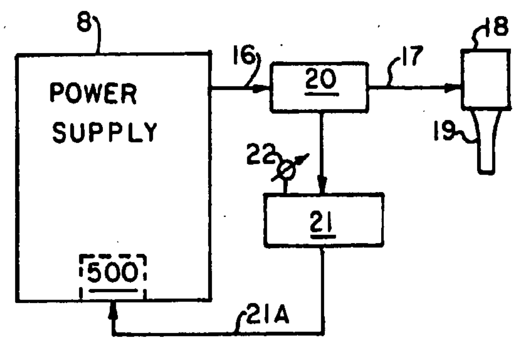


FIG.5.

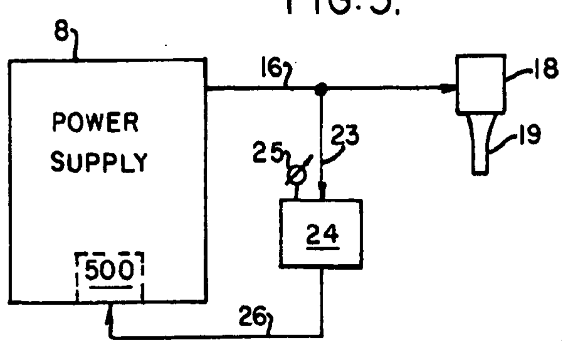


FIG.6.

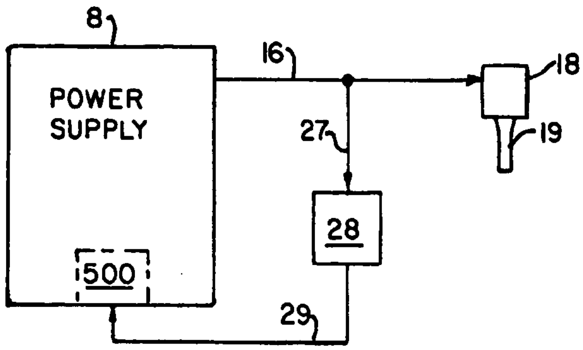


FIG.7.

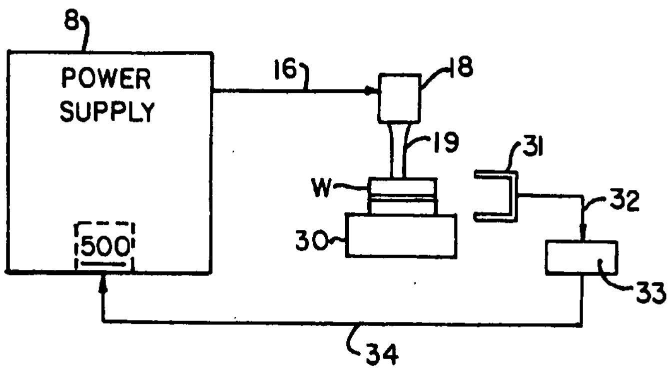


FIG.8.

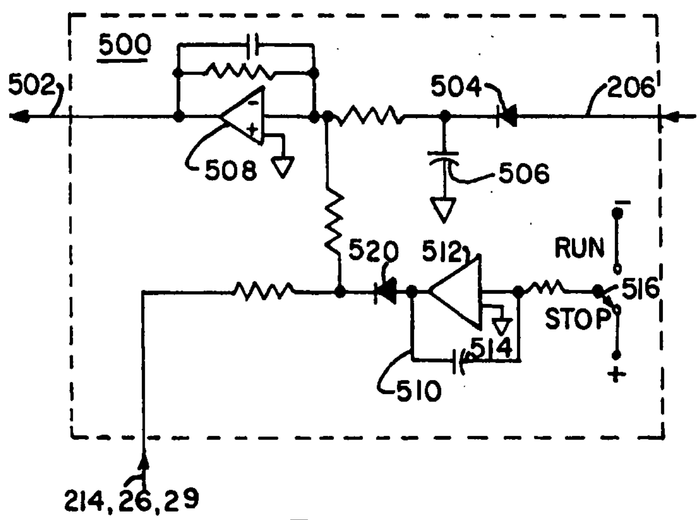


FIG.9.

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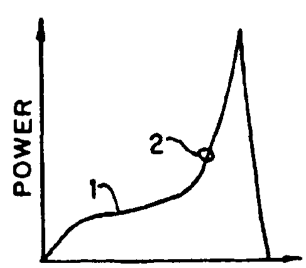


FIG.1.

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# EUROPEAN SEARCH REPORT

Application Number
EP 93 63 0029

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int.Cl.5) |
|---|---|---|---|
| X,D<br>Y | US-A-4 973 876 (ROBERTS)<br>* the whole document * | 1-4,6, 11,12, 17,18,20<br>5,7-10, 13,19 | B06B1/02<br>B29C65/08<br>B23K1/06<br>G05D19/02 |
| X,D<br>Y,D | US-A-4 631 685 (PETER)<br>* abstract; claims 1,7,8; figures 5,6 * | 14,15<br>5,8,16 | |
| Y | US-A-4 770 730 (ABE)<br>* abstract * | 10 | |
| Y | PATENT ABSTRACTS OF JAPAN<br>vol. 12, no. 8 (P-654)12 January 1988<br>& JP-A-62 168 208 (SHIMAZU CORP) 24 July 1987<br>* abstract * | 5,7,9, 10,13, 16,19 | |
| A | PATENT ABSTRACTS OF JAPAN<br>vol. 10, no. 187 (M-493)2 July 1986<br>& JP-A-61 030 367 (NIPPON DENSHI KOGYO KK) 12 February 1986<br>* abstract * | 1 | |

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

B06B
B23K
G05D
B29C

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 28 February 1994 | De Heering, P |

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